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1 [Dynamic simulation of autonomous legged locomotion](#)



Michael McKenna, David Zeltzer

September 1990

ACM SIGGRAPH Computer Graphics , Proceedings of the 17th annual conference on Computer graphics and interactive techniques SIGGRAPH '90, Volume 24 Issue 4

Publisher: ACM Press

Full text available: [pdf\(2.81 MB\)](#)Additional Information: [full citation](#), [abstract](#), [references](#), [citations](#), [index terms](#)

Accurate simulation of Newtonian mechanics is essential for simulating realistic motion of joined figures. Dynamic simulation requires, however, a large amount of computation when compared to kinematic methods, and the control of dynamic figures can be quite complex. We have implemented an efficient forward dynamic simulation algorithm for articulated figures which has a computational complexity linear in the number of joints. In addition, we present a strategy for the coordination of the locomotion ...

2 [Goal-directed, dynamic animation of human walking](#)



A. Bruderlin, T. W. Calvert

July 1989

ACM SIGGRAPH Computer Graphics , Proceedings of the 16th annual conference on Computer graphics and interactive techniques SIGGRAPH '89, Volume 23 Issue 3

Publisher: ACM Press

Full text available: [pdf\(3.05 MB\)](#)Additional Information: [full citation](#), [abstract](#), [references](#), [citations](#), [index terms](#)

This paper presents a hybrid approach to the animation of human locomotion which combines goal-directed and dynamic motion control. Knowledge about a locomotion cycle is incorporated into a hierarchical control process. The desired locomotion is conveniently specified at the top level as a task (e.g. walk at speed v), which is then decomposed by application of the concepts of *step symmetry* and *state-phase-timings*. As a result of this decomposition, the forces and torques ...

3 [Controlling dynamic simulation with kinematic constraints](#)



Paul M. Isaacs, Michael F. Cohen

August 1987

ACM SIGGRAPH Computer Graphics , Proceedings of the 14th annual conference on Computer graphics and interactive techniques SIGGRAPH '87, Volume 21 Issue 4



Publisher: ACM Press

Full text available: [pdf\(956.16 KB\)](#)Additional Information: [full citation](#), [abstract](#), [references](#), [citations](#), [index terms](#)

Theoretical and numerical aspects of the implementation of a DYNAMIC MOTION system, dubbed DYNAMO, for the dynamic simulation of linked figures is presented. The system introduces three means for achieving control of the resulting motion which have not been present in previous dynamic simulation systems for computer animation. (1) "Kinematic constraints" permit traditional keyframe animation systems to be embedded within a dynamic analysis. Joint limit constraints are also handled correctly ...


4


[Production and playback of human figure motion for visual simulation](#)

-  John P. Granieri, Jonathan Crabtree, Norman I. Badler
 July 1995 **ACM Transactions on Modeling and Computer Simulation (TOMACS)**, Volume 5 Issue 3
 Publisher: ACM Press
 Full text available:  pdf(1.68 MB) Additional Information: [full citation](#), [abstract](#), [references](#), [citations](#), [index terms](#)


We describe a system for off-line production and real-time playback of motion for articulated human figures in 3D virtual environments. The key notion are (1) the logical storage of full-body motion in posture graphs, which provides a simple motion access method for playback, and (2) mapping the motions of high DOF figures to lower DOF figures using slaving to provide human models at several levels of detail, both in geometry and articulation, for later playback. We present our system in th ...

Keywords: animation, multiresolution motion, posture graphs, real-time animation, visual simulation

- 5 Multi-dimensional input techniques and articulated figure positioning by multiple constraints 

Norman I. Badler, Kamran H. Manoochchhri, David Baraff
 January 1987 **Proceedings of the 1986 workshop on Interactive 3D graphics**
 Publisher: ACM Press
 Full text available:  pdf(1.34 MB) Additional Information: [full citation](#), [abstract](#), [references](#), [citations](#), [index terms](#)


A six degree-of-freedom input device presents some novel possibilities for manipulating and positioning three-dimensional objects. Some experiments in using such a device in conjunction with a real-time display are described. A particular problem which arises in positioning an articulated figure is the solution of three-dimensional kinematics subject to multiple joint position goals. A method using such an input device to interactively determine positions and a constraint satisfaction algor ...


- 6 Computational modeling for the computer animation of legged figures 

Michael Girard, A. A. Maciejewski
 July 1985 **ACM SIGGRAPH Computer Graphics , Proceedings of the 12th annual conference on Computer graphics and interactive techniques SIGGRAPH '85**, Volume 19 Issue 3
 Publisher: ACM Press
 Full text available:  pdf(654.08 KB) Additional Information: [full citation](#), [abstract](#), [references](#), [citations](#), [index terms](#)

Modeling techniques for animating legged figures are described which are used in the PODA animation system. PODA utilizes pseudoinverse control in order to solve the problems associated with manipulating kinematically redundant limbs. PODA builds on this capability to synthesize a kinematic model of legged locomotion which allows animators to control the complex relationships between the motion of the body of a figure and the coordination of its legs. Finally, PODA provides for the integration o ...

Keywords: computational modeling, legged locomotion, manipulators, motion control

- 7 Inverse kinematics positioning using nonlinear programming for highly articulated figures 

Jianmin Zhao, Norman I. Badler
 October 1994 **ACM Transactions on Graphics (TOG)**, Volume 13 Issue 4
 Publisher: ACM Press
 Full text available:  pdf(2.23 MB) Additional Information: [full citation](#), [abstract](#), [references](#), [citations](#), [index terms](#), [review](#)

An articulated figure is often modeled as a set of rigid segments connected with joints. Its configuration can be altered by varying the joint angles. Although it is straight forward to compute figure configurations given joint angles (forward kinematics), it is more difficult to find the joint angles for a desired configuration (inverse kinematics). Since the inverse kinematics problem is of special importance to an animator wishing to set a figure to a posture satisfying a set of position ...

Keywords: articulated figures, inverse kinematics, nonlinear programming

- 8 Simulation, motion capture, editing: Motion capture-driven simulations that hit and 

**react**

Victor Brian Zordan, Jessica K. Hodgins

July 2002

Proceedings of the 2002 ACM SIGGRAPH/Eurographics symposium on Computer animation

Publisher: ACM Press

Full text available: pdf(6.90 MB)

Additional Information: [full citation](#), [abstract](#), [references](#), [citations](#), [index terms](#)

Controllable, reactive human motion is essential in many video games and training environments. Characters in these applications often perform tasks based on modified motion data, but response to unpredicted events is also important in order to maintain realism. We approach the problem of motion synthesis for interactive, humanlike characters by combining dynamic simulation and human motion capture data. Our control systems use trajectory tracking to follow motion capture data and a balance control ...

Keywords: computer games, motion capture and human body simulation, physically based animation, virtual environments

**9 Computing curricula 2001**

September 2001

Journal on Educational Resources in Computing (JERIC)

Publisher: ACM Press

Full text available: pdf(613.63 KB) html(2.78 KB)

Additional Information: [full citation](#), [references](#), [citations](#), [index terms](#)**10 Interactive behaviors for bipedal articulated figures**

Cary B. Phillips, Norman I. Badler

July 1991

ACM SIGGRAPH Computer Graphics , Proceedings of the 18th annual conference on Computer graphics and interactive techniques SIGGRAPH '91, Volume 25 Issue 4

Publisher: ACM Press

Full text available: pdf(1.83 MB)

Additional Information: [full citation](#), [abstract](#), [references](#), [citations](#), [index terms](#)

We describe techniques for interactively controlling bipedal articulated figures through kinematic constraints. These constraints model certain behavioral tendencies which capture some of the characteristics of human-like movement, and give us control over such elements as the figures' balance and stability. They operate in near real-time, so provide behavioral control for interactive manipulation. These constraints form the basis of an interactive motion-generation system that allows the active ...

Keywords: articulated figures, balance, behavioral animation, interactive manipulation, inverse kinematics

**11 Simulation, motion capture, editing: Modeling tension and relaxation for computer animation**

Michael Neff, Eugene Fiume

July 2002

Proceedings of the 2002 ACM SIGGRAPH/Eurographics symposium on Computer animation

Publisher: ACM Press

Full text available: pdf(3.44 MB)

Additional Information: [full citation](#), [abstract](#), [references](#), [citations](#), [index terms](#)

The use of tension and relaxation in the muscles of real creatures gives rise to nuanced motion that conveys emotion or intent. Artists have long exploited knowledge of this in traditional animation and other areas, but it has been both overlooked and difficult to achieve in physically based animation. The robotically stiff motion that has come to typify physically based approaches belies the fact that dynamics has much to offer in facilitating far more subtle motion in which animators could free ...

Keywords: animation, human body simulation, physically based animation


**12 Strength guided motion**

Philip Lee, Susanna Wei, Jianmin Zhao, Norman I. Badler

September 1990

ACM SIGGRAPH Computer Graphics , Proceedings of the 17th annual conference on Computer graphics and interactive techniques SIGGRAPH '90, Volume 24 Issue 4

Publisher: ACM Press

Full text available:  pdf(2.17 MB)Additional Information: [full citation](#), [abstract](#), [references](#), [citations](#), [index terms](#)

A methodology and algorithm are presented that generate motions imitating the way humans complete a lifting task under various loading conditions. The path taken depends on "natural" parameters: the figure geometry, the given load, the final destination, and, especially, the *strength model* of the agent. Additional user controllable parameters of the motion are the *comfort* of the action and the *perceived exertion* of the agent. The algorithm uses this information to incrementa ...


13 Synthesis of complex dynamic character motion from simple animations

C. Karen Liu, Zoran Popović

July 2002

ACM Transactions on Graphics (TOG) , Proceedings of the 29th annual conference on Computer graphics and interactive techniques SIGGRAPH '02, Volume 21 Issue 3

Publisher: ACM Press

Full text available:  pdf(5.75 MB)Additional Information: [full citation](#), [abstract](#), [references](#), [citations](#), [index terms](#)

In this paper we present a general method for rapid prototyping of realistic character motion. We solve for the natural motion from a simple animation provided by the animator. Our framework can be used to produce relatively complex realistic motion with little user effort. We describe a novel constraint detection method that automatically determines different constraints on the character by analyzing the input motion. We show that realistic motion can be achieved by enforcing a small set of line ...

Keywords: animation, animation w/constraints, motion transformation, physically based animation, physically based modeling, spacetime constraints

14 Movement control methods for complex, dynamically simulated agents: Adonis

dances the Macarena

Maja J. Mataric, Victor Brian Zordan, Zachary Mason

May 1998

Proceedings of the second international conference on Autonomous agents

Publisher: ACM Press


Full text available:  pdf(1.08 MB)Additional Information: [full citation](#), [references](#), [citations](#), [index terms](#)15 Simulation of object and human skin formations in a grasping task

J.-P. Gourret, N. M. Thalmann, D. Thalmann

July 1989

ACM SIGGRAPH Computer Graphics , Proceedings of the 16th annual conference on Computer graphics and interactive techniques SIGGRAPH '89, Volume 23 Issue 3

Publisher: ACM Press

Full text available:  pdf(3.26 MB)Additional Information: [full citation](#), [abstract](#), [references](#), [citations](#), [index terms](#)

This paper addresses the problem of simulating deformations between objects and the hand of a synthetic character during a grasping process. A numerical method based on finite element theory allows us to take into account the active forces of the fingers on the object and the reactive forces of the object on the fingers. The method improves control of synthetic human behavior in a task level animation system because it provides information about the environment of a synthetic human and so can be ...


16 Interactive design of 3-D computer-animated legged animal motion

Michael Girard

January 1987



Proceedings of the 1986 workshop on Interactive 3D graphics

Publisher: ACM Press

Full text available:  pdf(1.44 MB)Additional Information: [full citation](#), [abstract](#), [references](#), [citations](#), [index terms](#)



We present a visually interactive approach to the design of 3-D computer-animated legged animal motion in the context of the PODA computer animation system. The design process entails the interactive specification of parameters which drive a computational model for animal movement. The animator incrementally modifies a framework for establishing desired limb and body motion as well as the constraints imposed by physical dynamics (Newtonian mechanical properties) and temporal restrictions. P ...

17 Realistic animation of rigid bodies

-  James K. Hahn
June 1988 **ACM SIGGRAPH Computer Graphics , Proceedings of the 15th annual conference on Computer graphics and interactive techniques SIGGRAPH '88**, Volume 22 Issue 4
Publisher: ACM Press
Full text available:  [pdf\(884.32 KB\)](#) Additional Information: [full citation](#), [abstract](#), [references](#), [citations](#), [index terms](#)



The theoretical background and implementation for a computer animation system to model a general class of three dimensional dynamic processes for arbitrary rigid bodies is presented. The simulation of the dynamic interaction among rigid bodies takes into account various physical characteristics such as elasticity, friction, mass, and moment of inertia to produce rolling and sliding contacts. If a set of bodies is statically unstable, the system dynamically drives it toward a stable configuration ...

Keywords: dynamics, modeling, rigid bodies, simulation

- 18 Interactive control for physically-based animation
 Joseph Laszlo, Michiel van de Panne, Eugene Fiume
July 2000 **Proceedings of the 27th annual conference on Computer graphics and interactive techniques**
Publisher: ACM Press/Addison-Wesley Publishing Co.
Full text available:  [pdf\(197.96 KB\)](#) Additional Information: [full citation](#), [abstract](#), [references](#), [citations](#), [index terms](#)



We propose the use of interactive, user-in-the-loop techniques for controlling physically-based animated characters. With a suitably designed interface, the continuous and discrete input actions afforded by a standard mouse and keyboard allow for the creation of a broad range of motions. We apply our techniques to interactively control planar dynamic simulations of a bounding cat, a gymnastic desk lamp, and a human character capable of walking, running, climbing, and various gymnastic behavior ...

Keywords: physically based animation, user interfaces

- 19 Gross motion planning—a survey
 Yong K. Hwang, Narendra Ahuja
September 1992 **ACM Computing Surveys (CSUR)**, Volume 24 Issue 3
Publisher: ACM Press
Full text available:  [pdf\(6.40 MB\)](#) Additional Information: [full citation](#), [abstract](#), [references](#), [citations](#), [index terms](#), [review](#)

Motion planning is one of the most important areas of robotics research. The complexity of the motion-planning problem has hindered the development of practical algorithms. This paper surveys the work on gross-motion planning, including motion planners for point robots, rigid robots, and manipulators in stationary, time-varying, constrained, and movable-object environments. The general issues in motion planning are explained. Recent approaches and their performances are briefly described, a ...

Keywords: collision detection, computational geometry, implementation, motion planning, obstacle avoidance, path planning, spatial representation

- 20 A physically realistic framework for the generation of high-level animation controllers
 Olivier Parisy, Christophe Schlick
June 2002 **Proceedings of the 2nd international symposium on Smart graphics SMARTGRAPH '02**
Publisher: ACM Press
Full text available:  [pdf\(634.21 KB\)](#) Additional Information: [full citation](#), [abstract](#), [references](#)

Artificial life techniques can be seen as an evolution of animation techniques, shifting most of the low-level control tasks traditionally performed by an animator to control systems, which can be manually (task-driven animation) or automatically (behavioural animation) handled. In this last situation, a rich environment from which interesting strategies can be extracted by evolutive creatures is needed. We will describe here a simulation framework that we developed for this purpose, and show how ...

Keywords: animation, artificial life., behaviour, high-level control, simulation